

3190R-02

TITLE

## FRICTION MODIFIERS FOR IMPROVED ANTI-SHUDDER PERFORMANCE AND HIGH STATIC FRICTION IN TRANSMISSION FLUIDS

5 This application claims priority from United States Provisional Applications 60/395,374 (12 July 2002) and 60/418,601 (15 October 2002).

BACKGROUND OF THE INVENTION

10 [0001] The present invention relates to the field of additives for fluids such as automatic transmission fluids, traction fluids, fluids for continuously variable transmission fluids (CVTs), dual clutch automatic transmission fluids, farm tractor fluids, and engine lubricants.

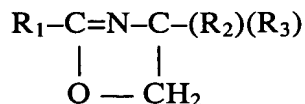
15 [0002] In the automatic transmission marketplace, where there is rapid engineering change driven by the desire to reduce weight and increase transmission capacity, there is a desire for automatic transmission fluids that exhibit a high static coefficient of friction for improved clutch holding capacity. At the same time, there is a desire to improve the retention of positive slope characteristics in the  $\mu/v$  (coefficient of friction vs. sliding speed) curve. There are newer tests in the marketplace which are used to define these characteristics. The static torque can be measured in tests such as the Toyota SAE#2 friction test procedure and the retention of positive slope can be measured by procedures like the JASO LVFA (Japan Automotive Standards Organization, Low Velocity Friction Apparatus) in which the slope of the  $\mu/v$  curve is periodically measured during oxidative and mechanical aging.

20 [0003] There are patents, for example, US 5,750,476, where a type of friction modifier technology used to achieve this performance is described. The combined requirements of high static coefficient of friction and durable positive slope are often incompatible with traditional ATF friction modifier technology which is extremely well described in the patent literature. Many of the commonly used friction modifiers result in a low static coefficient of friction and are not durable enough on positive slope to be of sufficient use. Additional patent literature describing technology for retaining positive  $\mu/v$  or anti-shudder characteristics include US 5,858,929. These may employ metal detergents and combinations of friction modifiers.

25 [0004] U.S. Patent 4,886,612 discloses a lubricating oil comprising at least one of various products, which can be various imidazolines or an oxazoline of the structure

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where  $R_2$  and  $R_3$  each represent  $CH_2OCOR_1$ ,  $CH_2OH$  or  $H$ .

5 [0005] The present invention, therefore, solves the problem of developing new friction modifiers to obtain high static coefficients of friction and maintaining a durable positive slope during oxidative and mechanical stressing of the friction system, particularly in an automatic transmission by the use of a friction modifier prepared by the condensation a carboxylic acid (or a reactive equivalent thereof) with an amino alcohol; for example, the condensation of two moles of  
10 isostearic acid with one mole of tris-hydroxymethylaminomethane (THAM).

#### SUMMARY OF THE INVENTION

[0006] The present invention provides a composition suitable for use in fluids such as transmission fluids, including automatic, continuously variable, dual  
15 clutch, and manual transmission fluids, as well as farm tractor fluids, engine lubricants, as well a gears and bearings, comprising the following components:

A fluid composition, comprising:

(a) a friction modifier derived from the reaction of a carboxylic acid or a reactive equivalent thereof with an aminoalcohol, wherein the friction modifier  
20 contains at least two hydrocarbyl groups, each containing at least 6 carbon atoms; (Examples include the reaction product of isostearic acid or an alkyl succinic anhydride with tris-hydroxymethylaminomethane); and

(b) a dispersant other than a species of (a).

[0007] The present invention further provides a method for lubricating a  
25 mechanical device such as transmission, tractor, engine, gearbox, or bearing, comprising supplying to said device the above composition; or supplying a composition comprising the above-described friction modifier.

#### DETAILED DESCRIPTION OF THE INVENTION

[0008] Various preferred features and embodiments will be described below  
30 by way of non-limiting illustration.

[0009] Component (a) is a friction modifier with at least two substituent hydrocarbyl groups, for example, alkyl groups. Specific examples of this type of component include the following condensation products:

Isostearic acid/Trishydroxymethylamino methane ("THAM")(2:1 mole ratio);  
35 Isostearic acid / 2-Amino-2-ethyl-1,3-propanediol (2:1 mole ratio);  
Octadecyl succinic anhydride / ethanol amine / isostearic acid (1:1:1 mole ratio);

and any of the foregoing materials combined with propylene oxide (in, e.g., a 1:1 mole ratio).

5 [0010] These materials are derived by the condensation of an acid (1) with an aminoalcohol (2). The usual intention is to produce molecules which contain at least two hydrocarbyl groups attached to one central polar group. In order to assure a reasonable degree of oil solubility for the product, the two hydrocarbyl groups should, together, contain a total of at least 8 carbon atoms, preferably at least 12 or 16 carbon atoms. Each such hydrocarbyl groups is typically a long chain alkyl groups containing, individually, at least 6 or 8 carbon atoms, such as 10 to 30, or 12 to 24, or 14 to 20, or 16 to 18 carbon atoms. In certain embodiments one or two of the components of the condensation product contain branched chains.

15 [0011] In each type of condensation product, the organo carboxylic acids or equivalents (e.g., anhydrides, acid halides, esters) (1) may be as shown in the specific examples, or be a similar carboxylic acid derived from fatty acids from natural plant and animal oils or synthetically produced. They are, generally, in the 8 to 30 carbon atom range and are substantially linear in character. Alternatively, they may contain 10 to 24 carbon atoms, or 12 to 22 or 16 to 20 carbon atoms. Examples are stearic acid, palmitic acid, oleic acid, tall oil acids, acids derived from the oxidation of hydrocarbons, substituted succinic acids, ether-acids derived from the addition of acrylates or methacrylates to alcohols, and the like. (The reaction products of the ether-acids will contain the requisite hydrocarbyl groups provided that the groups exhibit substantially hydrocarbon character despite the presence of the ether functionality, as further described in the definition of "hydrocarbyl," below.) Mixtures of acids can also be used, e.g., 20 isostearic acid and octadecyl succinic acid or -anhydride, such mixtures being useful when reacted with an aminoalcohol such as ethanolamine, described below.

30 [0012] The amine containing material (2) is an aminoalcohol, that is, a molecule containing both amine functionality and alcohol functionality. The amine functionality is preferably in the form of a nitrogen atom containing at least one replaceable hydrogen, that is, a primary or secondary amine. Examples of amino alcohols are tris-hydroxymethylaminomethane, 2-amino-2-ethyl-1,3-propanediol, and ethanol amine. Other amino alcohols are also of use in this 35 condensation, including 3-amino-1-propanol, 2-amino-1-propanol, 1-amino-2-propanol, 2-amino-2-methyl-1-propanol, 4-amino-1-butanol, 5-amino-1-pentanol, 2-amino-1-pentanol, 2-amino-1,2-propanediol, 2-amino-1,3-propane-

diol, 2-amino-2-methyl-1,3-propanediol, N-(2-hydroxyethyl)ethylenediamine, N,N-bis(2-hydroxyethyl)ethylenediamine, 1,3-diamino-2-hydroxypropane, N-N'-bis-(2-hydroxyethyl)ethylenediamine, and 1-aminopropyl-3-diisopropanol amine.

5 [0013] The two hydrocarbyl groups present in component (a) generally originate from the hydrocarbyl portion of the acid reactant. In that case it is generally desirable that 2 moles of acid be reacted with 1 mole of the aminoalcohol, each of the two moles thereby providing one long chain hydrocarbyl group. This ratio may generally vary from 1.2:1 to 3:1, or 1.6:1 to 2.5:1, or 1.9:1 to  
10 2.1:1. It is recognized that in any reaction product there may be a mixture of products, and reacting in any of the above ratios may lead to some 1:1 adduct, 2:1 adduct, 3:1 adduct, and so on, in statistical or other ratios depending in part on the relative amounts of the starting materials. The fact that the product may include a portion of the 1:1 adduct does not remove such a product from the  
15 scope of the present invention, provided that at least a portion of the product contains the required two hydrocarbyl groups. Of course, if two different species of acid are used, the ratios can be about 1:1:1, and so on; provided that the ratio moles of all such acids to the moles of all the aminoalcohols will normally be about 2:1. Alternatively, if the aminoalcohol itself is the source of one long  
20 chain hydrocarbyl group, then a ratio of about 1:1 may be appropriate to provide the two hydrocarbyl groups per molecule. Such variations will be apparent to the person skilled in the art.

[0014] The amount of component (a) in the compositions of the present invention is generally 0.2 to 5.0 percent by weight of the finished fluid formulation.  
25 Preferably the amount of component (a) is 0.5 to 4 percent of the finished fluid formulation. More preferably the amount of component (a) is 1.0 to 2.5 percent of the finished fluid formulation.

[0015] Component (b) is a dispersant. It is described as "other than a species of (a)," in the event that some of the friction modifiers of (a) may exhibit some  
30 dispersant characteristics. Examples of "carboxylic dispersants" are described in many U.S. Patents including the following: 3,219,666, 3,316,177, 3,340,281, 3,351,552, 3,381,022, 3,433,744, 3,444,170, 3,467,668, 3,501,405, 3,542,680, 3,576,743, 3,632,511, 4,234,435, and Re 26,433.

[0016] Succinimide dispersants, a species of carboxylic dispersants, are  
35 prepared by the reaction of a hydrocarbyl-substituted succinic anhydride (or reactive equivalent thereof, such as an acid, acid halide, or ester) with an amine, as described above. The hydrocarbyl substituent group generally contains an

average of at least 8, or 20, or 30, or 35 up to 350, or to 200, or to 100 carbon atoms. In one embodiment, the hydrocarbonyl group is derived from a polyalkene. Such a polyalkene can be characterized by an  $\overline{M}_n$  (number average molecular weight) of at least 500. Generally, the polyalkene is characterized by an  $\overline{M}_n$  of 500, or 700, or 800, or 900 up to 5000, or to 2500, or to 2000, or to 1500. In another embodiment  $\overline{M}_n$  varies from 500, or 700, or 800, to 1200 or 1300. In one embodiment the polydispersity ( $\overline{M}_w/\overline{M}_n$ ) is at least 1.5.

[0017] The polyalkenes include homopolymers and inter-polymers of polymerizable olefin monomers of 2 to 16 or to 6, or to 4 carbon atoms. The olefins may be monoolefins such as ethylene, propylene, 1-butene, isobutene, and 1-octene; or a polyolefinic monomer, such as diolefinic monomer, such 1,3-butadiene and isoprene. In one embodiment, the inter-polymer is a homopolymer. An example of a polymer is a polybutene. In one instance about 50% of the polybutene is derived from isobutylene. The polyalkenes can be prepared by conventional procedures.

[0018] In one embodiment, the succinic acylating agents are prepared by reacting a polyalkene with an excess of maleic anhydride to provide substituted succinic acylating agents wherein the number of succinic groups for each equivalent weight of substituent group is at least 1.3, e.g., 1.5, or 1.7, or 1.8. The maximum number of succinic groups per substituent group generally will not exceed 4.5, or 2.5, or 2.1, or 2.0. The preparation and use of substituted succinic acylating agents wherein the substituent is derived from such polyolefins are described in U.S. Patent 4,234,435.

[0019] The substituted succinic acylating agent can be reacted with an amine, including those amines described above and heavy amine products known as amine still bottoms. The amount of amine reacted with the acylating agent is typically an amount to provide a mole ratio of CO:N of 1:2 to 1:0.75, . If the amine is a primary amine, complete condensation to the imide can occur. Varying amounts of amide product, such as the amidic acid, may also be present. If the reaction is, rather, with an alcohol, the resulting dispersant will be an ester dispersant. If both amine and alcohol functionality are present, whether in separate molecules or in the same molecule (as in the above-described condensed amines), mixtures of amide, ester, and possibly imide functionality can be present. These are the so-called ester-amide dispersants.

[0020] "Amine dispersants" are reaction products of relatively high molecular weight aliphatic or alicyclic halides and amines, preferably polyalkylene poly-

amines. Examples thereof are described in the following U.S. Patents: 3,275,554, 3,438,757, 3,454,555, and 3,565,804.

5 [0021] "Mannich dispersants" are the reaction products of alkyl phenols in which the alkyl group contains at least 30 carbon atoms with aldehydes (especially formaldehyde) and amines (especially polyalkylene polyamines). The materials described in the following U.S. Patents are illustrative: 3,036,003, 3,236,770, 3,414,347, 3,448,047, 3,461,172, 3,539,633, 3,586,629, 3,591,598, 3,634,515, 3,725,480, 3,726,882, and 3,980,569.

10 [0022] Post-treated dispersants are also part of the present invention. They are generally obtained by reacting at carboxylic, amine or Mannich dispersants with reagents such as urea, thiourea, carbon disulfide, aldehydes, ketones, carboxylic acids, hydrocarbon-substituted succinic anhydrides, nitriles, epoxides, boron compounds (to give "borated dispersants"), or phosphorus compounds. Exemplary materials of this kind are described in the following U.S. Patents:  
15 3,200,107, 3,282,955, 3,367,943, 3,513,093, 3,639,242, 3,649,659, 3,442,808, 3,455,832, 3,579,450, 3,600,372, 3,702,757, and 3,708,422.

[0023] Also included are dispersants that have been treated with boric acid, phosphorus acids or anhydrides, and 2,5-dimercaptothiadiazole (DMTD). Mixtures of dispersants can also be used.

20 [0024] The amount of component (b) in the compositions of the present invention are generally 1.0 to 4.0%. Preferably the amount of component (b) is 2.0 to 3.0%. More preferably the amount of component (b) is 2.2% to 2.8% of the final blended fluid formulation.

25 [0025] Other components which are conventionally employed in a transmission fluid, in particular, and automatic transmission fluid (ATF) are typically also present.

30 [0026] Among such components are an oil of lubricating viscosity. Such oils include natural and synthetic lubricating oils and mixtures thereof. In a fully formulated lubricant, the oil of lubricating viscosity is generally present in a major amount (i.e. an amount greater than 50 percent by weight). Typically, the oil of lubricating viscosity is present in an amount of 75 to 95 percent by weight, and often greater than 80 percent by weight of the composition.

35 [0027] Natural oils useful in making the inventive lubricants and functional fluids include animal oils and vegetable oils as well as mineral lubricating oils such as liquid petroleum oils and solvent-treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic or mixed paraffinic/-naphthenic types which may be further refined by hydrocracking and hydrofinishing processes.

[0028] Synthetic lubricating oils include hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and interpolymerized olefins, also known as polyalphaolefins; polyphenyls; alkylated diphenyl ethers; alkyl- or dialkylbenzenes; and alkylated diphenyl sulfides; and the derivatives, analogs  
5 and homologues thereof. Also included are alkylene oxide polymers and interpolymers and derivatives thereof, in which the terminal hydroxyl groups may have been modified by esterification or etherification. Also included are esters of dicarboxylic acids with a variety of alcohols, or esters made from C5 to C12 monocarboxylic acids and polyols or polyol ethers. Other synthetic oils include  
10 silicon-based oils, liquid esters of phosphorus-containing acids, and polymeric tetrahydrofurans.

[0029] Unrefined, refined and rerefined oils, either natural or synthetic, can be used in the lubricants of the present invention. Unrefined oils are those obtained directly from a natural or synthetic source without further purification  
15 treatment. Refined oils have been further treated in one or more purification steps to improve one or more properties. They can, for example, be hydrogenated, resulting in oils of improved stability against oxidation.

[0030] In one embodiment, the oil of lubricating viscosity is a Group II or a group III oil, or a synthetic oil, or mixtures thereof. Group II and Group III oils are classifications established by the API Base Oil Interchangeability Guidelines.  
20 Both Group II and Group III oils contain < 0.03 percent sulfur and > 99 percent saturates. Group II oils have a viscosity index of 80 to 120, and Group III oils have a viscosity index > 120. Polyalphaolefins are categorized as Group IV. The oil can also be an oil derived from a Fischer-Tropsch synthesis.

[0031] In a preferred embodiment, at least 50% by weight of the oil of lubricating viscosity is a polyalphaolefin (PAO). Typically, the polyalphaolefins are derived from monomers having from 4 to 30, or from 4 to 20, or from 6 to 16 carbon atoms. Examples of useful PAOs include those derived from 1-decene. These PAOs may have a viscosity of 1.5 to 150 mm<sup>2</sup>/s (cSt) at 100°C. PAOs are  
25 typically hydrogenated materials.

[0032] The oils of the present invention can encompass oils of a single viscosity range or a mixture of high viscosity and low viscosity range oils. In a preferred embodiment, the oil exhibits a 100°C kinematic viscosity of 1 or 2 to 8 or 10 mm<sup>2</sup>/sec (cSt). The overall lubricant composition is preferably formulated  
35 using oil and other components such that the viscosity at 100°C is 1 or 1.5 to 10 or 15 or 20 mm<sup>2</sup>/sec and the Brookfield viscosity (ASTM-D-2983) at -40°C is

less than 20 or 15 Pa-s (20,000 cP or 15,000 cP), preferably less than 10 Pa-s, even 5 or less.

[0033] The composition used in the present invention can also include a variety of additional components. One component frequently used is a viscosity modifier. Viscosity modifiers (VM) and dispersant viscosity modifiers (DVM) are well known. Examples of VMs and DVMs are polymethacrylates, polyacrylates, polyolefins, styrene-maleic ester copolymers, and similar polymeric substances including homopolymers, copolymers and graft copolymers.

[0034] Examples of commercially available VMs, DVMs and their chemical types include the following: polyisobutylenes (such as Indopol™ from BP Amoco or Parapol™ from ExxonMobil); Olefin copolymers (such as Lubrizol™ 7060, 7065, and 7067 from Lubrizol and Trilene™ CP-40 and CP-60 from Uniroyal); hydrogenated styrene-diene copolymers (such as Shellvis™ 40 and 50, from Shell and LZ® 7341, 7351, and 7441 from Lubrizol); Styrene/maleate copolymers, which are dispersant copolymers (such as LZ® 3702, 3715, and 3703 from Lubrizol); polymethacrylates, some of which have dispersant properties (such as those in the Acryloid™ and Viscoplex™ series from RohMax, the TLA™ series from Texaco, and LZ 7702™ and LZ 7720™ from Lubrizol); olefin-graft-polymethacrylate polymers (such as Viscoplex™ 2-500 and 2-600 from Rohm GmbH); and hydrogenated polyisoprene star polymers (such as Shellvis™ 200 and 260, from Shell). Recent summaries of viscosity modifiers can be found in U.S. patents 5,157,088, 5,256,752 and 5,395,539. The VMs and/or DVMs are incorporated into the fully-formulated compositions at a level of up to 15% by weight. Preferred amounts are 1 to 12 % or 3 to 10 %.

[0035] Another component that may be used in the composition used in the present invention is a supplemental friction modifier. Friction modifiers are well known to those skilled in the art. A useful list of friction modifiers is included in U.S. Pat. No. 4,792,410. U.S. Patent 5,110,488 discloses metal salts of fatty acids and especially zinc salts, useful as friction modifiers. A list of friction modifiers includes:

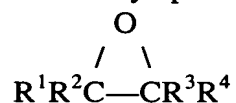
- (i) fatty phosphites
- (ii) fatty acid amides
- (iii) fatty epoxides
- (iv) borated fatty epoxides
- (v) fatty amines
- (vi) glycerol esters
- (vii) borated glycerol esters



- (viii) alkoxyated fatty amines
- (ix) borated alkoxyated fatty amines
- (x) metal salts of fatty acids
- (xi) sulfurized olefins
- 5 (xii) fatty imidazolines
- (xiii) condensation products of carboxylic acids and polyalkylene-polyamines
- (xiv) metal salts of alkyl salicylates
- (xv) amine salts of alkylphosphoric acids
- 10 and mixtures thereof.

[0036] Representatives of each of these types of friction modifiers are known and are commercially available. For instance, (i) fatty phosphites are generally of the formula  $(RO)_2PHO$ . The preferred dialkyl phosphite, as shown in the preceding formula, is typically present with a minor amount of monoalkyl phosphite of the formula  $(RO)(HO)PHO$ . In these structures, the term "R" is conventionally referred to as an alkyl group. It is, of course, possible that the alkyl is actually alkenyl and thus the terms "alkyl" and "alkylated," as used herein, will embrace other than saturated alkyl groups within the phosphite. The phosphite should have sufficient hydrocarbyl groups to render the phosphite substantially oleophilic. Preferably the hydrocarbyl groups are substantially unbranched. Many suitable phosphites are available commercially and may be synthesized as described in U.S. Patent 4,752,416. It is preferred that the phosphite contain 8 to 24 carbon atoms in each of R groups. Preferably, the fatty phosphite contains 12 to 22 carbon atoms in each of the fatty radicals, most preferably 16 to 20 carbon atoms. In one embodiment the fatty phosphite can be formed from oleyl groups, thus having 18 carbon atoms in each fatty radical.

[0037] (iv) Borated fatty epoxides are known from Canadian Patent No. 1,188,704. These oil-soluble boron- containing compositions are prepared by reacting, at a temperature from 80°C to 250°C, boric acid or boron trioxide with at least one fatty epoxide having the formula



wherein each of  $R^1$ ,  $R^2$ ,  $R^3$  and  $R^4$  is hydrogen or an aliphatic radical, or any two thereof together with the epoxy carbon atom or atoms to which they are attached, form a cyclic radical. The fatty epoxide preferably contains at least 8 carbon atoms.

[0038] The borated fatty epoxides can be characterized by the method for their preparation which involves the reaction of two materials. Reagent A can be boron trioxide or any of the various forms of boric acid including metaboric acid ( $\text{HBO}_2$ ), orthoboric acid ( $\text{H}_3\text{BO}_3$ ) and tetraboric acid ( $\text{H}_2\text{B}_4\text{O}_7$ ). Boric acid, and especially orthoboric acid, is preferred. Reagent B can be at least one fatty epoxide having the above formula. In the formula, each of the R groups is most often hydrogen or an aliphatic radical with at least one being a hydrocarbyl or aliphatic radical containing at least 6 carbon atoms. The molar ratio of reagent A to reagent B is generally 1:0.25 to 1:4. Ratios of 1:1 to 1:3 are preferred, with about 1:2 being an especially preferred ratio. The borated fatty epoxides can be prepared by merely blending the two reagents and heating them at temperature of  $80^\circ$  to  $250^\circ\text{C}$ , preferably  $100^\circ$  to  $200^\circ\text{C}$ , for a period of time sufficient for reaction to take place. If desired, the reaction may be effected in the presence of a substantially inert, normally liquid organic diluent. During the reaction, water is evolved and may be removed by distillation.

[0039] (iii) Non-borated fatty epoxides, corresponding to "Reagent B" above, are also useful as friction modifiers.

[0040] Borated amines are generally known from U.S. Patent 4,622,158. Borated amine friction modifiers (including (ix) borated alkoxyated fatty amines) are conveniently prepared by the reaction of a boron compounds, as described above, with the corresponding amines. The amine can be a simple fatty amine or hydroxy containing tertiary amines. The borated amines can be prepared by adding the boron reactant, as described above, to an amine reactant and heating the resulting mixture at a  $50^\circ$  to  $300^\circ\text{C}$ , preferably  $100^\circ\text{C}$  to  $250^\circ\text{C}$  or  $150^\circ\text{C}$  to  $230^\circ\text{C}$ , with stirring. The reaction is continued until by-product water ceases to evolve from the reaction mixture indicating completion of the reaction.

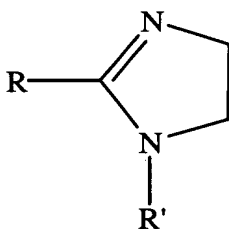
[0041] Among the amines useful in preparing the borated amines are commercial alkoxyated fatty amines known by the trademark "ETHOMEEN" and available from Akzo Nobel. Representative examples of these ETHOMEEN<sup>TM</sup> materials is ETHOMEEN<sup>TM</sup> C/12 (bis[2-hydroxyethyl]-coco-amine); ETHOMEEN<sup>TM</sup> C/20 (polyoxyethylene[10]cocoamine); ETHOMEEN<sup>TM</sup> S/12 (bis[2-hydroxyethyl]soyamine); ETHOMEEN<sup>TM</sup> T/12 (bis[2-hydroxyethyl]-tallow-amine); ETHOMEEN<sup>TM</sup> T/15 (polyoxyethylene-[5]tallowamine); ETHOMEEN<sup>TM</sup> 0/12 (bis[2-hydroxyethyl]oleyl-amine); ETHOMEEN<sup>TM</sup> 18/12 (bis[2—hydroxyethyl]octadecylamine); and ETHOMEEN<sup>TM</sup> 18/25 (polyoxyethyl-ene[15]octadecylamine). Fatty amines and ethoxylated fatty amines are also described in U.S. Patent 4,741,848.

[0042] The (viii) alkoxylated fatty amines, and (v) fatty amines themselves (such as oleylamine) are generally useful as friction modifiers in this invention. Such amines are commercially available.

5 [0043] Both borated and unborated fatty acid esters of glycerol can be used as friction modifiers. The (vii) borated fatty acid esters of glycerol are prepared by borating a fatty acid ester of glycerol with boric acid with removal of the water of reaction. Preferably, there is sufficient boron present such that each boron will react with from 1.5 to 2.5 hydroxyl groups present in the reaction mixture. The reaction may be carried out at a temperature in the range of 60°C to 135°C, in  
10 the absence or presence of any suitable organic solvent such as methanol, benzene, xylenes, toluene, or oil.

[0044] (vi) Fatty acid esters of glycerol themselves can be prepared by a variety of methods well known in the art. Many of these esters, such as glycerol monooleate and glycerol tallowate, are manufactured on a commercial scale. The  
15 esters useful are oil-soluble and are preferably prepared from C8 to C22 fatty acids or mixtures thereof such as are found in natural products and as are described in greater detail below. Fatty acid monoesters of glycerol are preferred, although, mixtures of mono- and diesters may be used. For example, commercial glycerol monooleate may contain a mixture of 45% to 55% by weight monoester and 55% to 45% diester.  
20

[0045] Fatty acids can be used in preparing the above glycerol esters; they can also be used in preparing their (x) metal salts, (ii) amides, and (xii) imidazolines, any of which can also be used as friction modifiers. Preferred fatty acids are those containing 6 to 24 carbon atoms, preferably 8 to 18. The acids can be  
25 branched or straight-chain, saturated or unsaturated. Suitable acids include 2-ethylhexanoic, decanoic, oleic, stearic, isostearic, palmitic, myristic, palmitoleic, linoleic, lauric, and linolenic acids, and the acids from the natural products tallow, palm oil, olive oil, peanut oil, corn oil, and Neat's foot oil. A particularly preferred acid is oleic acid. Preferred metal salts include zinc and calcium salts.  
30 Examples are overbased calcium salts and basic oleic acid-zinc salt complexes which can be represented by the general formula  $Zn_4Oleate_3O_1$ . Preferred amides are those prepared by condensation with ammonia or with primary or secondary amines such as diethylamine and diethanolamine. Fatty imidazolines are the cyclic condensation product of an acid with a diamine or polyamine such  
35 as a polyethylenepolyamine. The imidazolines are generally represented by the structure



[0046] where R is an alkyl group and R' is hydrogen or a hydrocarbyl group or a substituted hydrocarbyl group, including  $-(CH_2CH_2NH)_n-$  groups. In a preferred embodiment the friction modifier is the condensation product of a C8 to C24 fatty acid with a polyalkylene polyamine, and in particular, the product of isostearic acid with tetraethylenepentamine. The condensation products of carboxylic acids and polyalkyleneamines (xiii) may generally be imidazolines or amides.

[0047] Sulfurized olefins (xi) are well known commercial materials used as friction modifiers. A particularly preferred sulfurized olefin is one which is prepared in accordance with the detailed teachings of U.S. Patents 4,957,651 and 4,959,168. Described therein is a cosulfurized mixture of 2 or more reactants selected from the group consisting of (1) at least one fatty acid ester of a polyhydric alcohol, (2) at least one fatty acid, (3) at least one olefin, and (4) at least one fatty acid ester of a monohydric alcohol.

[0048] Reactant (3), the olefin component, comprises at least one olefin. This olefin is preferably an aliphatic olefin, which usually will contain 4 to 40 carbon atoms, preferably from 8 to 36 carbon atoms. Terminal olefins, or alpha-olefins, are preferred, especially those having from 12 to 20 carbon atoms. Mixtures of these olefins are commercially available, and such mixtures are contemplated for use in this invention.

[0049] The cosulfurized mixture of two or more of the reactants, is prepared by reacting the mixture of appropriate reactants with a source of sulfur. The mixture to be sulfurized can contain 10 to 90 parts of Reactant (1), or 0.1 15 parts by weight of Reactant (2); or 10 to 90 parts, often 15 to 60 parts, more often 25 to 35 parts by weight of Reactant (3), or 10 to 90 parts by weight of reactant (4). The mixture, in the present invention, includes Reactant (3) and at least one other member of the group of reactants identified as reactants (1), (2) and (4). The sulfurization reaction generally is effected at an elevated temperature with agitation and optionally in an inert atmosphere and in the presence of an inert solvent. The sulfurizing agents useful in the process of the present invention include elemental sulfur, which is preferred, hydrogen sulfide, sulfur

halide plus sodium sulfide, and a mixture of hydrogen sulfide and sulfur or sulfur dioxide. Typically often 0.5 to 3 moles of sulfur are employed per mole of olefinic bonds.

5 [0050] Metal salts of alkyl salicylates (xiv) include calcium and other salts of long chain (e.g. C12 to C16) alkyl-substituted salicylic acids.

[0051] Amine salts of alkylphosphoric acids (xv) include salts of oleyl and other long chain esters of phosphoric acid, with amines as described below. Useful amines in this regard are tertiary-aliphatic primary amines, sold under the tradename Primene™. The supplemental friction modifier can be used in  
10 addition to component (a). The amount of the supplemental friction modifier is generally 0.1 to 1.5 percent by weight of the lubricating composition, preferably 0.2 to 1.0 or 0.25 to 0.75 percent.

[0052] The compositions of the present invention can also include a detergent. Detergents as used herein are metal salts of organic acids. The organic acid  
15 portion of the detergent is a sulfonate, carboxylate, phenate, salicylate. The metal portion of the detergent is an alkali or alkaline earth metal. Preferred metals are sodium, calcium, potassium and magnesium. Typically, the detergents are overbased, meaning that there is a stoichiometric excess of metal over that needed to form the neutral metal salt.

20 [0053] Preferred overbased organic salts are the sulfonate salts having a substantially oleophilic character and which are formed from organic materials. Organic sulfonates are well known materials in the lubricant and detergent arts. The sulfonate compound should contain on average 10 to 40 carbon atoms, preferably 12 to 36 carbon atoms and preferably 14 to 32 carbon atoms on  
25 average. Similarly, the phenates, salicylates, and carboxylates have a substantially oleophilic character.

[0054] While the present invention allows for the carbon atoms to be either aromatic or in paraffinic configuration, it is preferred that alkylated aromatics be employed. While naphthalene based materials may be employed, the aromatic of  
30 choice is the benzene moiety.

[0055] The most preferred composition is thus an overbased monosulfonated alkylated benzene, and is preferably the monoalkylated benzene. Typically, alkyl benzene fractions are obtained from still bottom sources and are mono- or di-alkylated. It is believed, in the present invention, that the mono-alkylated  
35 aromatics are superior to the dialkylated aromatics in overall properties.

[0056] It is desired that a mixture of mono-alkylated aromatics (benzene) be utilized to obtain the mono-alkylated salt (benzene sulfonate) in the present

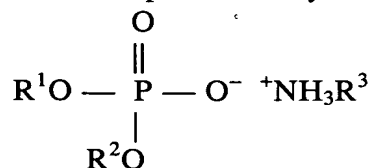
invention. The mixtures wherein a substantial portion of the composition contains polymers of propylene as the source of the alkyl groups assist in the solubility of the salt. The use of mono-functional (e.g., mono-sulfonated) materials avoids crosslinking of the molecules with less precipitation of the salt from the lubricant.

[0057] It is preferred that the salt be "overbased." By overbasing, it is meant that a stoichiometric excess of the metal be present over that required to neutralize the anion of the salt. The excess metal from overbasing has the effect of neutralizing acids which may build up in the lubricant. A second advantage is that the overbased salt increases the dynamic coefficient of friction. Typically, the excess metal will be present over that which is required to neutralize the anion at in the ratio of up to 30:1, preferably 5:1 to 18:1 on an equivalent basis.

[0058] The amount of the overbased salt utilized in the composition is typically 0.025 to 3 weight percent on an oil free basis, preferably 0.1 to 1.0 percent. The overbased salt is usually made up in about 50% oil with a TBN range of 10-600 on an oil free basis. Borated and non-borated overbased detergents are described in U.S. Patents 5,403,501 and 4,792,410 which are herein incorporated by reference for disclosure pertinent hereto.

[0059] The compositions of the present invention can also include at least one phosphorus acid, phosphorus acid salt, phosphorus acid ester or derivative thereof including sulfur-containing analogs in the amount of 0.002-1.0 weight percent. The phosphorus acids, salts, esters or derivatives thereof include phosphoric acid, phosphorous acid, phosphorus acid esters or salts thereof, phosphites, phosphorus-containing amides, phosphorus-containing carboxylic acids or esters, phosphorus-containing ethers, and mixtures thereof.

[0060] In one embodiment, the phosphorus acid, ester or derivative can be an organic or inorganic phosphorus acid, phosphorus acid ester, phosphorus acid salt, or derivative thereof. The phosphorus acids include the phosphoric, phosphonic, phosphinic, and thiophosphoric acids including dithiophosphoric acid as well as the monothiophosphoric, thiophosphinic and thiophosphonic acids. One group of phosphorus compounds are alkylphosphoric acid mono alkyl primary amine salts as represented by the formula



where R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup> are alkyl or hydrocarbyl groups or one of R<sup>1</sup> and R<sup>2</sup> can be H. The materials can be a 1:1 mixture of dialkyl and monoalkyl phosphoric acid esters. Compounds of this type are described in U.S. Patent 5,354,484.

5 [0061] Eighty-five percent phosphoric acid is a preferred material for addition to the fully-formulated compositions and can be included at a level of 0.01-0.3 weight percent based on the weight of the composition, preferably 0.03 to 0.1 percent.

10 [0062] Other materials can optionally be included in the compositions of the present invention, provided that they are not incompatible with the aforementioned required components or specifications. Such materials include antioxidants (that is, oxidation inhibitors), including hindered phenolic antioxidants, secondary aromatic amine antioxidants, sulfurized phenolic antioxidants, oil-soluble copper compounds, phosphorus-containing antioxidants, organic sulfides, disulfides, and polysulfides. Other optional components include seal  
15 swell compositions, such as isodecyl sulfolane or phthalate esters, which are designed to keep seals pliable. Also permissible are pour point depressants, such as alkylnaphthalenes, polymethacrylates, vinyl acetate/fumarate or /maleate copolymers, and styrene/maleate copolymers. These optional materials are known to those skilled in the art, are generally commercially available, and are  
20 described in greater detail in published European Patent Application 761,805. Also included can be corrosion inhibitors, dyes, fluidizing agents, odor masking agents, and antifoam agents.

[0063] The above components can be in the form of a fully-formulated lubricant or in the form of a concentrate within a smaller amount of lubricating  
25 oil. If they are present in a concentrate, their concentrations will generally be directly proportional to their concentrations in the more dilute form in the final blend.

#### EXAMPLES

[0064] Examples 1- 14 are prepared in the following base formulation:

	<u>amount (%)</u> :
100N Base oil	60.2
55N-60N Base oil	25.8
Dispersant (b)	2.4
DMTD treated dispersant	0.6
Alkyl dimercaptothiadiazole	0.03
Mono&dialkyldiphenyl amines (alkyl groups can include butyl, heptyl, octyl, nonyl)	0.6

2-Propanol, 1-(tert-dodecylthio)-	0.5
Alkyl sulfone seal swell agent	0.4
Borated C14 to C18 epoxide	0.2
<b>Component (a)</b> (as defined below)	2.5 or in another amount as illustrated below
Polymethacrylate pour point depressant	0.2
Polymethacrylate viscosity modifier	4
Dialkyl hydrogen phosphite antiwear agent	0.11
Oil diluent	0.26
85% Phosphoric acid	0.1
Red dye	0.025
Polydimethylsiloxane, 10% solution	0.03

**[0065]** Testing of the compositions described above is carried out as follows: The static friction is expressed in term of  $\mu T$  or the stabilized static coefficient from the SAE#2 test procedure. The test procedure is described in the Japanese Automobile Standard, JASO M-348-95, "Test method for friction property of automatic transmission fluids".

**[0066]** Testing gives the following results:

Ex.	Base formulation + component (a) as shown below	Toyota SAE #2 Average $\mu T$	JASO LVFA Screen Average Slope X 10
1	"Good Reference" – a commercial formulation	0.153	0.048
2	Base + 0.5% Isostearic acid/polyamine friction modifier *	0.131	0.012
3	Base without friction modifier ("FM") *	0.189	-0.112
4	Base + 0.5% ODSA/DETA (2:1) (Reference FM) *	0.186	0.011
5	Base + 2.5% ODSA/DETA (2:1) (Reference FM) *	0.169	0.033
6	Base + 0.5% Dilauryl phosphite *	0.173	-0.096
7	Base + 0.5% Ethomeen C-12 *	0.137	-0.120
8	Base + 0.5% Oleic acid/Diethanolamine (1:1)m *	0.152	0.003
9	Base + 0.5% commercial synthetic ester friction modifier *	0.185	-0.043
10	Base + 2.5% Octadecylsuccinic anhydride/Duomeen T(1:1)m *	0.139	0.043
11	Base + 2.5% Isostearic Acid/Duomeen T(1:1)m *	0.103	0.105
12	Base + 2.5% Isostearic Acid/THAM(2:1)m	<b>0.156</b>	<b>0.041</b>
13	Base + 0.5% Glycerol Monooleate *	0.174	-0.004
14	Base + 0.5% Ethomeen T-12 *	0.138	—



\* -- a comparative example.

ODSA = Octadecylsuccinic anhydride

5 [0067] It is preferred that  $\mu T$  is equivalent or better than the "Good Reference" and the Slope X10 is as high as possible compared to the "Good Reference" ATF. In some preferred examples,  $\mu T$  is at least 0.150 and the average slope is positive, e.g., greater than 0.033 or at least 0.040.

10 [0068] The results show that the friction modifier (a) in combination with the dispersant (b) provide a high level of static friction  $\mu T$  while the slope of the JASO LVFA screen test remains positive for 40 hours. These results are equivalent to the Reference oil exhibiting these properties.

Example 15.

[0069] A lubricant formulation is prepared by combining the following components (percentages are by weight):

15 0.30 % product of isostearic acid and THAM (2:1 mole ratio)  
0.375 % dispersant from polybutene substituted succinic anhydride and diethanolamine (including 33% diluent oil)  
0.20 % polybutene substituted succinic anhydride  
1.0 % dialkyl hydrogen phosphite  
20 0.5 % borate ester  
1.15 % zinc dialkyl dithiophosphates (including 11% diluent oil)  
0.2 % amine salt of alkyl phosphate  
3.0 % overbased calcium sulfonate detergent (including 52% diluent oil)  
200 ppm antifoam agent  
25 balance: base oil formulation (including viscosity modifier) and additional diluent oil.

[0070] The formulation of Example 15 is subjected to the SAE #2 friction test and found to have a static coefficient of friction of 0.108-0.109. The coefficients of friction at 1200 r.p.m. ( $\mu_{1200}$ ) and 0 r.p.m. ( $\mu_0$ ) are measured, and the value of  $\mu_0/\mu_{1200}$  determined to be 1.025. The formulation thereby exhibits good friction performance for use as a tractor hydraulic fluid.

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Example 16.

[0071] A lubricant formulation suitable for use as an engine oil lubricant is prepared by combining the following components (percentages by weight):

35 0.2% product of isostearic acid and THAM (2:1 mole ratio)  
5.1% succinimide dispersant (including 55% diluent oil)

1.53% overbased calcium alkylbenzenesulfonate detergent(s), TBN 300-400 (including 42% diluent oil)

0.20 % hindered phenol ester antioxidant

0.70% amine antioxidant

5 0.98% zinc dialkyldithiophosphate (including 9% oil)

0.1% sulfurized olefin (including 5% oil)

90 ppm commercial antifoam product

balance: base oil formulation (including viscosity modifier) and additional diluent oil.

10 Examples 17 and 18.

[0072] The following formulations are prepared suitable for use as automatic transmission lubricants (amounts in parts by weight):

Material	Ex. 17	Ex. 18
API Group 2 base oil	100	100
Methacrylate polymer pour point depressant (35-40% oil)	0.30	0.20
Methacrylate copolymer viscosity modifier, nitrogen containing (with 26.5% oil)	5.0	5.0
Succinimide dispersant(s) (40-43% oil)	4.0	4.2
Dimercaptothiadiazole-containing dispersant (49% oil)	0.50	1.00
Borated succinimide dispersant (33% oil)	0.50	
Product of isostearic acid and THAM (2:1 mole ratio)	1.25	1.25
Borate ester friction modifier	0.20	0.20
Overbased Ca alkylbenzenesulfonate detergent, 300 TBN (50% oil)	0.30	0.07
Ca alkylbenzenesulfonate detergent, 10 TBN (50% oil)	0.84	
Dibutyl hydrogen phosphite anti-wear agent	0.20	0.11
85% Aqueous phosphoric acid	0.03	0.10
Dimercaptothiadiazole oxidation inhibitor	0.03	0.04
Aromatic amine oxidation inhibitor	0.40	0.60
Sulfurized alcohol oxidation inhibitor	0.50	0.50
Sulfolane seal swell agent	0.80	1.20
Commercial antifoam product(s)	0.03	0.034
Dye	0.025	0.025
Odorant	0.002	0.002
Additional diluent oil	0.45	0.53

[0073] The formulations of Examples 17 and 18 meet the requirements of the MerconV® low speed test for antishudder. The MerconV® low speed test defines the acceptable antishudder requirements for automatic transmission fluids for Ford Motor Company vehicles. These formulations show that the friction modifier component is effective in formulations having very high (Ex. 17) to very low (Ex. 18) ash content as contributed by calcium alkylbenzene sulfonate detergent(s).

[0074] As used herein, the term "hydrocarbyl substituent" or "hydrocarbyl group" is used in its ordinary sense, which is well-known to those skilled in the art. Specifically, it refers to a group having a carbon atom directly attached to the remainder of the molecule and having predominantly hydrocarbon character. Examples of hydrocarbyl groups include:

hydrocarbon substituents, that is, aliphatic (e.g., alkyl or alkenyl), alicyclic (e.g., cycloalkyl, cycloalkenyl) substituents, and aromatic-, aliphatic-, and alicyclic-substituted aromatic substituents, as well as cyclic substituents wherein the ring is completed through another portion of the molecule (e.g., two substituents together form a ring);

substituted hydrocarbon substituents, that is, substituents containing non-hydrocarbon groups which, in the context of this invention, do not alter the predominantly hydrocarbon substituent (e.g., halo (especially chloro and fluoro), hydroxy, alkoxy, mercapto, alkylmercapto, nitro, nitroso, and sulfoxy);

hetero substituents, that is, substituents which, while having a predominantly hydrocarbon character, in the context of this invention, contain other than carbon in a ring or chain otherwise composed of carbon atoms. Heteroatoms include sulfur, oxygen, nitrogen, and encompass substituents as pyridyl, furyl, thienyl and imidazolyl. In general, no more than two, preferably no more than one, non-hydrocarbon substituent will be present for every ten carbon atoms in the hydrocarbyl group; typically, there will be no non-hydrocarbon substituents in the hydrocarbyl group.

[0075] It is known that some of the materials described above may interact in the final formulation, so that the components of the final formulation may be different from those that are initially added. For instance, metal ions (of, e.g., a detergent) can migrate to other acidic sites of other molecules. The products formed thereby, including the products formed upon employing the composition of the present invention in its intended use, may not be susceptible of easy description. Nevertheless, all such modifications and reaction products are included

within the scope of the present invention; the present invention encompasses the composition prepared by admixing the components described above.

[0076] Each of the documents referred to above is incorporated herein by reference. Except in the Examples, or where otherwise explicitly indicated, all numerical quantities in this description specifying amounts of materials, reaction conditions, molecular weights, number of carbon atoms, and the like, are to be understood as modified by the word "about." Unless otherwise indicated, each chemical or composition referred to herein should be interpreted as being a commercial grade material which may contain the isomers, by-products, derivatives, and other such materials which are normally understood to be present in the commercial grade. However, the amount of each chemical component is presented exclusive of any solvent or diluent oil which may be customarily present in the commercial material, unless otherwise indicated. It is to be understood that the upper and lower amount, range, and ratio limits set forth herein may be independently combined. As used herein, the expression "consisting essentially of" permits the inclusion of substances which do not materially affect the basic and novel characteristics of the composition under consideration.